Renewable and Sustainable Energy Reviews 15 (2011) 4548–4553

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review of energy efficiency potentials in tropical buildings – Perspective of enclosed common areas

Qi Jie Kwong*, Yusoff Ali

Department of Mechanical and Materials Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

ARTICLE INFO

Article history:
Received 29 March 2011
Accepted 5 July 2011
Available online 29 September 2011

Keywords:
Energy efficiency
Common areas
Human comfort
Tropical building

ABSTRACT

Effective use of energy is crucial due to the continuously depleting energy resources, especially for developing countries which are currently experiencing rapid economic and population growth. Enclosed common areas in buildings are designed to accommodate the needs of occupants. Such spaces often constitute a large portion of the total building spaces and subjected to a certain degree of building services requirement which contributes to the increase in energy consumption. Hence, it is important to understand the special characteristics of the common areas in buildings for energy efficiency improvement whilst maintaining human comfort. This paper reviews the studies conducted in the common areas of buildings, and sought to introduce a new approach in building energy efficiency improvement. In tropical buildings, a large portion of energy is being used on the air conditioning and artificial lighting systems to sustain the occupants' comfort. This has raised concerns on effective use of the systems and hence suggesting an additional opportunity in energy efficiency improvement.

Contents

1. Introduction

The rapid economic growth in the developing countries has lead to increase in energy consumption and supply difficulties. Hence, efficient usage of energy is essential in preserving the amount of energy sources available. The energy used by nations which are developing will exceed the advanced countries by 2020 [1]. The final commercial energy demand is commonly divided into several sectors: industrial, transport, resident and commercial, non-energy, agricultural and forestry. In Malaysia, both the residential and commercial sectors had consumed 213 Peta-joules of energy in 2005 and is expected to grow to 284.9 Peta-joules in the year 2010 as shown in Table 1 [2]. The energy demand is expected to grow at an average rate of 6.3% per annum between year 2005 and 2010. This is mostly due to the rapid development of economic activities and population growth, as well as the increasing demand for comfort and a higher standard lifestyle that has consequently caused a significant increase in energy consumption.

In most tropical buildings, the air conditioning system is essential in maintaining good thermal environment for occupants. Yet, it is often the largest consumer of energy in which 30–60% of the building's energy is used for cooling and dehumidification purposes. Artificial lighting comes second in energy consumption after air conditioning system, and yields 15–20% of the total energy consumption [3]. In general, the building spaces can be divided into two sections: the commonly occupied ones and the common areas. Conventionally, less energy related studies were directed towards the latter with various reasons, such as difficulties in conducting field measurements, complexity of the physical phenomenon involved and the transient nature of these areas. In this paper, the available

* Corresponding author. Tel.: +60 3 8921 6106; fax: +60 3 8925 2546.
E-mail address: kwong@eng.ukm.my (Q.J. Kwong).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2011.07.097

Table 1
Commercial energy demand by sector, Malaysia, 2000–2010 [2].

Source	Petajoules			Percentage			Average annual growth rate	
	2000	2005	2010	2000	2005	2010	8MP	9MP
Industrial	477.6	630.7	859.9	38.4	38.6	38.8	5.7	6.4
Transport	505.5	661.3	911.7	40.6	40.5	41.1	5.5	6.6
Residential & commercial	162.0	213.0	284.9	13.0	13.1	12.8	5.6	6.0
Non-energy	94.2	118.7	144.7	7.6	7.3	6.5	4.7	4.0
Agriculture and forestry	4.4	8.0	16.7	0.4	0.5	0.8	12.9	15.9
Total	1243.7	1631.7	2217.9	100.0	100.0	100.0	5.6	6.3

information concerning comfort studies performed at the common areas in buildings are analyzed with the aim to identify opportunities for energy efficiency improvement.

2. Enclosed common areas in building

A building is made up of different compartments to serve various types of human activities. Other than the normally occupied regions such as classrooms, offices, and meeting rooms, the common areas are designed to allow occupants to travel either between outdoors and the interior usable spaces or within interior spaces which are separately located [4], and available in various architectural designs. Common areas can be divided into two types: the fully enclosed ones (surrounded inside a building) and the building parts opened to the outdoor environment. The enclosed common areas in building are generally viewed as the regions which are not actively occupied by people, subjected to some building services requirement and not directly connected with the external environment. It is also known as the transitional zones, and some of the examples of these areas are the lift lobbies, passageways, corridors, indoor parking spaces, etc. [6].

In certain cases, the common areas may have several features that are similar to the occupied regions, where activities like setting of sales and promotion counters, meeting or discussion point are being conducted. The Uniform Building By-Laws 1984 (UBBL: 1984) [5] clearly stipulates several mandatory requirements in the common areas for safety of occupants. For example, by-laws 153 (1) of the UBBL: 1984 specifies that all protected lift lobbies must be equipped with fire smoke detectors. Besides, by-laws 200 stipulates the requirement for mechanical pressurization of staircase enclosure of Malaysian buildings. In other words, the thermal environment in such areas should be controlled by mechanical means which directly contribute to building's energy consumption. Fig. 1 shows the enclosed lift lobby of an educational institution in Malaysia which is installed with an air conditioning unit. The building services requirement – air conditioner, artificial lighting, fire detectors, etc. is presented in Fig. 2. The work of Pitts et al. [4] noted that the transitional spaces may take up 60% of the total building spaces. In other words, attention should be given to the enclosed common areas in terms of design and energy consumption, similar to the commonly occupied spaces.

Some researchers defined the common areas as the zones "between" architectural spaces where the indoor and outdoor climates are modified, without mechanical means and the people within the area may experience dynamic effects of change. Three types of transitional spaces are suggested by Chun et al. [6] and are shown in Fig. 3.

Each of the illustrated transitional spaces has different building services requirement. For example, type 1 transitional space may represent the lift lobby of an office, and is "fully enclosed" compared to type 3. Such "fully enclosed" common areas in tropical buildings are usually subjected to higher level of building services as required under several building design guidelines to sustain human comfort



Fig. 1. Enclosed lift lobby in a Malaysian building.



Fig. 2. Some examples of building services.

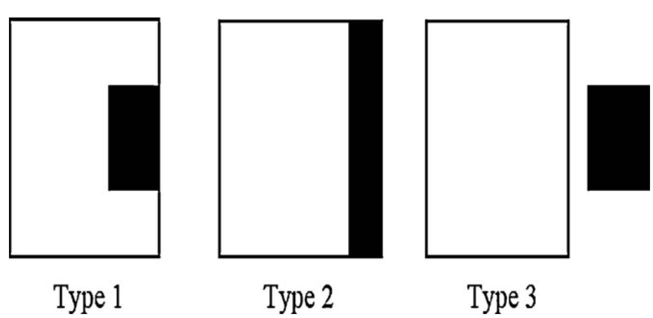


Fig. 3. Three types of transitional spaces [6].

and to ensure the protection of occupants' safety. Hence, due to the installation of mechanical devices, the authors propose that more work on energy efficiency improvement should be placed on this type of transitional space, as it forms a better opportunity in identifying areas for energy savings.

3. Environmental comfort in the common areas

To ensure the permanence of a healthy environment yet conducive for productivity of occupants, conditions of indoor environment must be adjusted to ensure environmental comfort [7,8]. Environmental comfort in the building comprises of four parameters: thermal, visual, acoustical and ergonomic comfort. According to ASHRAE Standard 55: 2004 [9], thermal comfort is defined as the condition of mind that expressed satisfaction with the thermal environment. Thermal comfort is essential in building, as thermal discomfort may directly affect the working performance of occupants [10]. Besides, illuminance level also has substantial influence towards human comfort [11]. However, most of the thermal comfort studies were conducted in the occupied spaces, such as offices and classrooms whilst fewer efforts were directed towards the common areas [4,24]. Even the ASHRAE Standard 55: 2004 [9] clearly mentioned in its scope that the standard only specifies thermal conditions acceptable for healthy adults at atmospheric pressure equivalent to altitudes up to 3000 m in indoor spaces designed for human occupancy for period not less than 15 min. In other words, the common areas are out of the contexts of the standard. Only until recently, a number of studies were conducted by researchers worldwide in the building transitional zones to clarify certain enquiries: the level of emotional interruption when travelers experienced sudden change in thermal experience [12,13], opportunity in energy efficiency improvement [4,14] and others. Despite all these efforts, there are still more spaces left for further analysis.

The work of Jitkhajornwanich and Pitts [12] in their work on thermal responses in transitional spaces in Bangkok found that the neutral temperature for such spaces may be higher, in which neutral temperature of 26.1–27.6 °C was found. The effect of air-conditioners on people, which lead to acclimatization to a controlled cooler environment and expectation of an unpleasantly warm sensation when encountering the outdoor environment was noted. This showed that although building users do not occupy the transitional spaces for a notable period of time, the indoor environment still exert some level of effects on human perceptions of thermal comfort. Pitts and Saleh [15] also found that such spaces act to modify experience and expectation of travelers passing through them.

In order to understand the characteristics of thermal comfort in the transitional spaces, Chun et al. [6] applied trial measurements in Japan and the physical variables measured were temperature, relative humidity, globe temperature, solar intensity and air velocity. The measurements were generally taken at the centre of the space, and the PMV (Predicted Mean Vote) model was applied for prediction of thermal comfort. The results obtained from the study proposed that transitional spaces can be defined as an independent dynamic space which owns various physical conditions. Also, the energy saving potential was suggested if they are developed according to the specific climate needs.

Another research conducted by Chun and Tamura [13] in urban transitional spaces with the objective to investigate thermal comfort for travelers applied the 7-point ASHRAE thermal sensation scale together with a laboratory study. The thermal comfort parameters were recorded concurrently and the conclusion made was thermal comfort in the transitional spaces can be adapted very widely. The reason for such statement was the fast temperature changes experienced by the building users while walking, unlike the activities in office buildings or houses. Thus, the conclusion made was narrow range of HVAC control is not required in the transitional spaces.

It is interesting to identify the different perception on thermal comfort for people who stayed in the transitional zones for a notable period of time (similar to commonly occupied conditions in certain extent) with the travelers who just merely passing by. A recent study conducted by Hwang et al. [14] with intention to identify the subjective responses and comfort perception in the transitional spaces for guests (short occupying period) and staffs (long occupying period) applying both objective and subjective measurements and was performed at a guest service centre in Taiwan. The outcomes of this research reflected the difference in thermal comfort preference, where the guests who entered from a warmer external environment showed preference towards a cooler surrounding. The acclimatization of workers was also demonstrated.

From all the studies performed in the common areas, it is identified that most of the environmental comfort studies considered only general observation, without distinctly specifying a particular region in a building for thermal comfort analysis. As suggested by Jitkhajornwanich and Pitts [12], internal environment have certain effects on human perception of thermal comfort regardless of the amount of time spent in a building region. By that means, it is important to allow thermal comfort studies to be conducted exclusively on one type of the transitional regions, as shown in the work of Hwang et al. [14] for better understanding of the occupants' thermal comfort preference as well as the opportunity for energy savings.

For measurement of thermal comfort parameters in an enclosed common area, which is crucial for comfort assessments, similar procedures as applied in the commonly occupied spaces can also be used as suggested in the work Chun et al. [6] and Chun and Tamura [13]. However, the transient environment of the common areas which are connected to the external environment is one of the major barriers in prediction of thermal and air flow rate. This has made the efforts of identifying the thermal sensation of occupants more difficult than in the occupied spaces. Yet, the enclosed type of common areas posted an opportunity as it features certain characteristics which are similar to the commonly occupied spaces [18].

The application of simulation software in thermal comfort survey is gaining popularity and acceptance recently. Several studies were conducted to predict the air movement and temperature profile of spaces inside a building [16,17,35] for energy efficiency improvement purposes. The simulation results often showed close resemblance of the actual measurements. Nevertheless, the prediction may be good in occupied spaces with controlled indoor environment only, since some of the common areas like passageways and corridors are often designed to act as a "buffer" zone between indoor and external environment. The thermal environment is not normally controlled via mechanical means and prediction of thermal comfort is more difficult to be made. As mentioned earlier in this paper, some of the transitional spaces may be treated as occupied spaces, as some activities which require human occupancy are often being conducted in such areas. In other words, the transitional spaces may be "enclosed" to maintain human comfort with the aid of mechanical cooling. And thus, the indoor conditions of the "enclosed" type of transitional spaces can be tested with references to the data from field measurements.

A case study was performed by Munisamy and Soong [17] on jet-fans application in a basement car park in Malaysia using Computational Fluid Dynamics (CFD) for energy efficiency improvement. The conditions of car park with jet-fans and without jet-fans were compared and the effectiveness of CFD in aid of

Table 2
Expectancy factors for non-conditioned buildings in warm climates [22].

Expectation	Classification of buildings		Expectancy factor, *e*
	Location	Warm periods	
High	Air-conditioned buildings are common	Occurring briefly during summer season	0.9–1.0
Moderate	Some air-conditioned buildings	Summer season	0.7–0.9
Low	Few air-conditioned buildings	All seasons	0.5–0.7

design evaluation was noted. Since people spend most of their time on indoor activities, Kaynakli and Kilic [19] investigated the indoor thermal comfort under transient condition by establishing a mathematical model of thermal interaction between human and their surroundings. The effect of clothing and air velocity were considered in this study. As human body was found to react significantly to the transient environment when they traveled from the common areas to their workplace, the building designers are expected to consider this fact in every phase of the building development for improvement in thermal comfort.

For thermal comfort assessments, it is necessary to apply some thermal comfort indices which are useful for prediction of thermal environment. The PMV model is an important and flexible tool for prediction of thermal sensation which considered the level of physical activity, clothing (CLO) value as well as the thermal comfort parameters: air temperature, relative humidity, mean radiant temperature and air velocity. Though well received in the buildings which are air-conditioned, several thermal comfort studies in tropical buildings concluded that the PMV model overestimated the thermal sensation of occupants [20,21], and is not suitable to be applied in the transitional space due to its dynamic physical features and behavior [6]. Fanger and Toftum [22] in their work of extension of the PMV model to non-air-conditioned buildings in warm climates introduce a list of expectancy factors for thermal comfort. The expectancy factor, *e*, is to be multiplied with the measured PMV to obtain the mean thermal sensation vote of the actual non-air-conditioned building in a tropical building. Table 2 presents the expectancy factors for non-air-conditioned buildings with different characteristics.

The expectancy factor is useful to apply together with the PMV model for prediction of human thermal sensation in tropical buildings, as it is noted to agree well with available quality field studies in non-air-conditioned buildings in warm climates. This serves as a useful tool in thermal comfort studies in the common areas, as the thermal conditions can be adopted very widely compared to occupied spaces [13] and good control of temperature and comfort limits are not required [15].

4. Energy savings potential

Effective energy usage is widely encouraged in Malaysia with the introduction of Malaysian Standard (MS) 1525: 2007 [23]. The standard specifies the code of practice on energy efficiency and use of renewable energy for non-residential buildings in Malaysia. In tropical buildings, the indoor environment is often air-conditioned due to higher climatic temperature. For buildings in Malaysia, the MS 1525:2007 [23] stipulates that the acceptable indoor temperature is in the range of 23–26 °C, with no building regions specified. This may be true for building spaces which are engaged with human activities, where several studies in the tropics have noted that temperature ranging between 23 and 26 °C is able to provide the occupants with thermally comfortable surroundings [24,25]. Though, the thermal requirement of the common areas is not specified explicitly in the standard. Some studies suggested that generally the occupants pay less attention to the environmental conditions of the common areas [15]. Besides, the energy efficiency potentials in some of the common areas were suggested. The work of Hwang et al. [26] suggested that the temperature setting for air conditioning system can be raised to 2 °C higher than the conventional settings for reduction in energy consumption, where every 1 °C increase in the thermostat setting may lead to a reduce of 6% in energy consumption [27]. Furthermore, it has shown in several studies that natural daylight is useful in reducing the usage of artificial lighting fixtures, which has introduced another area for energy efficiency improvement.

Pitts and Saleh [15] suggested that each type of transitional space can contribute in energy saving if the importance of such spaces is recognized in design and in energy use. Four types of transitional spaces were studied using thermal comfort indices and estimations were made on the energy saving potentials. The outcomes showed that improvement on energy efficiency can be obtained by allowing a modest relaxation of the comfort standards in transitional spaces. Further work was suggested to obtain more relevant data on transitional spaces in buildings.

5. Air Conditioning and Mechanical Ventilation (ACMV) system

The Air Conditioning and Mechanical Ventilation (ACMV) system typically accounts for one to two-thirds of the total energy consumption in buildings and often viewed as the potential candidate for improvement of energy efficiency [28,29]. As travelers were found to pay less attention on the amount of cooling acquired, design and operation of air conditioning systems in the enclosed common areas should not be made the same as the occupied spaces. The sizing of ACMV systems can be made with lower cooling load, together with the requirement for fan speed. For operational purpose, the acceptable range of temperature settings for each of the common areas should be studied specifically, as different common areas may have different thermal requirement. For example, Hwang et al. [26] and Kwong and Mariah [18] identified that people in the transitional spaces can be thermally comfortable, even with higher surrounding temperature. The travelers who walked through a passageway may have different thermal preferences than those who stayed for a longer period at the lift lobbies. This poses an interesting field for further surveys. As the PMV model often predict warmer environment than actual felt by occupants, the extension of PMV model introduced by Fanger and Toftum [22] has suggested expectancy factor for thermal comfort and should be considered to be applied in the thermal comfort studies of common areas inside tropical buildings.

Natural ventilation is always an interesting issue in buildings due to high energy consumption of the air conditioning system [35]. Some studies have noted the “acclimatization” of people living in the tropics to the warmer environment and suggested that occupants in tropical buildings may have different perception of thermal comfort than people in moderate climate [32,33]. Some common areas which are constructed to connect the indoor and external environment, such as outdoor passageways, are employing the concept of natural ventilation for energy savings purpose. However, the idea of using natural ventilation in the common areas to provide thermal comfort should be carefully studied to ensure that occupants’ safety is not jeopardized. This is due to the characteristics of

several common areas in which fire protection systems are required such as smoke and heat detectors. The application of natural ventilation may in certain extent, affect the functionality of the fire gadgets. In spite of that, studies can be conducted in such spaces to identify the possibility of minimizing energy consumption via equipment downsizing with reference to the available standards and regulations. The application of Overall Thermal Transfer Value (OTTV) for measurement of building envelop is suggested by the MS 1525: 2007 [23], and more detailed studies are required for Malaysia where the climate is hot and humid. Also, it should be noted that common areas in different building types may not have similar requirement in cooling loads. This fact lays a must for individual research in all common areas in order to obtain statistically accurate results.

6. Artificial lighting fixtures

Visual comfort is one of the most important comfort parameters. Human comfort is closely related with the illuminance level of the surroundings, where high solar intensity may lead to discomfort of occupants [30]. Artificial lighting is therefore necessary for all types of buildings to provide a suitable visual environment for the residents. The MS 1525: 2007 [23] stipulates the minimum requirement for illuminance level for common areas (termed "infrequently used area") in Malaysian buildings, as presented in Table 3. This serves as an important guideline for the building designers when it comes to the design of lighting fixtures in buildings. Nevertheless, the application of artificial lighting is contributing to the increase in energy consumption, and the work of Lam et al. [3] identified that the electric lighting accounts for 20–35% of total energy consumption in tropical buildings. The common areas are associated with high level of light fittings installation. For energy efficiency purpose, the use of free natural daylight as the source to provide sufficient illuminance level should be encouraged. This can be done during office hours (8.30 am to 5.00 pm) where the solar intensity is able to provide sufficient daylight illuminance, for example, 100 lux for lift lobby [23]. Li and Tsang [34] found that good building façade design utilizing daylight can reduce over 25% of total electric lighting energy. Yet, attention should be given to the issue of glare and solar heat gain in the common areas, as glass windows that have high value of transmittance are commonly available in tropical buildings. Common areas are unlike occupied spaces, where internal shading devices are often unavailable. This has suggested that some work must be carried out for identification of the "best approach" in designing for artificial lighting in the common areas – to ensure visual comfort with minimization of solar heat gain to the internal surrounding. The work of Li et al. [31] showed that improvement of glass windows using solar film coating were able to reduce energy consumption in both lighting and cooling systems, while sustaining visual comfort of occupants. Future studies on visual comfort in the common areas inside tropical buildings should take note of the transmittance level of glass enclosures applied, as well as the opportunity for application of shading devices for control of illuminance level during high solar intensity period.

Table 3
Recommended average illuminance levels for infrequently used area [23].

Example of applications	Illuminance (lux)
Minimum service illuminance	20
Interior walkway and car park	100
Corridor, passageways, stairs	100
Entrance and exit	100
Entrance hall, lobbies, waiting room	100
Inquiry desk	300
Gate house	100
Escalator	150

7. Conclusion

Energy consumption of Malaysian buildings comprises 13% of the total energy use and is expected to rise in the near future. This has made the energy efficiency strategies in buildings crucial, as it not only reduces the demand of useful energy, but also cuts down on the proliferation of CO_2 emissions. The increasing demand of air conditioning and artificial lighting for improvement of human comfort in the tropics greatly contributes to the increase in energy usage. The enclosed common area in buildings poses a fruitful opportunity in energy efficiency improvement, especially in tropical buildings because it constitutes a large portion of the total building space. More detail studies can be conducted in such area by focusing on thermal and other environmental comfort parameters, by applying field surveys, energy audits, software simulation, etc. It is strongly believed by the authors that the common areas can provide equal, if not more, potential for energy saving than the occupied spaces in tropical buildings. However, it is to be noted that energy efficiency strategies should be done in accordance to the occupants' comfort and safety, as buildings are built to serve human in various kind of activities.

References

[1] Lombard L, Ortiz J, Pout C. A review on buildings energy consumption information. Journal of Energy and Buildings 2008;40:394–8.
[2] United Nation Development Programme (UNDP). Achieving industrial energy efficiency in Malaysia. Malaysia: United Nation Development Programme; 2006.
[3] Lam JC, Li DHW, Cheung SO. An analysis of electricity end-use in air-conditioned office buildings in Hong Kong. Journal of Building and Environment 2003;38:493–8.
[4] Pitts A, Saleh J, Sharples S. Building transition spaces, comfort and energy use. In: 25th conference of passive and low energy architecture. 2008.
[5] Uniform Building By-Law (UBBL), UBBL (1984). Legal Research Board, International Law Book Services. Kuala Lumpur.
[6] Chun C, Kwok A, Tamura A. Thermal comfort in transitional spaces – basic concepts: literature review and trial measurement. Journal of Building and Environment 2004;39:1187–92.
[7] Oral GK, Yener AK, Bayazit NT. Building envelope design with the objective to ensure thermal, visual and acoustic comfort conditions. Journal of Building and Environment 2004;39:281–7.
[8] Srinavin K, Mohamed S. Thermal environment and construction workers' productivity: some evidence from Thailand. Journal of Building and Environment 2003;38:339–45.
[9] American Society of Heating, Refrigerating and air-conditioning engineers (ASHRAE), Standard 55. Thermal environment conditions for human occupancy. American Society of Heating, Ventilating and Air-Conditioning Engineers, USA; 2004.
[10] Kwok AG. Thermal comfort in tropical classrooms. ASHRAE Transactions 1998;104(1B):1031–47.
[11] Kruger EL, Zannin PHT. Acoustic, thermal and luminous comfort in classrooms. Journal of Building and Environment 2004;39:1055–63.
[12] Jitkhajornwanich K, Pitts A. Interpretation of thermal responses of four subject groups in transitional spaces of buildings in Bangkok. Journal of Building and Environment 2002;37:1193–204.
[13] Chun C, Tamura A. Thermal comfort in urban transitional spaces. Journal of Building and Environment 2005;40:633–9.
[14] Hwang RL, Lin TP, Kuo NJ. Field experiments on thermal comfort in campus classrooms in Taiwan. Journal of Energy and Buildings 2006;38:53–62.
[15] Pitts A, Saleh J. Potential for energy saving in building transition spaces. Journal of Energy and Building 2007;39:815–22.
[16] Cheong KWD, Djunaedy E, Chua YL, Tham KW, Sekhar SC, Wong NH, et al. Thermal comfort study of an air-conditioned lecture theatre in the tropics. Journal of Building and Environment 2003;38:63–73.
[17] Munisamy KM, Soong PS. Jet-Fan and CFD. Bulletin of the Institution of Engineers, Malaysia. Bil 2010 2010;2:30–1.
[18] Kwong QJ, Mariah NM. Energy efficiency potential in tropical buildings – Perspective of enclosed transitional zone. International Energy Journal 2011;11:111–22.
[19] Kaynakli O, Kilic M. Investigation of indoor thermal comfort under transient conditions. Journal of Building and Environment 2005;40:165–74.
[20] Wong NH, Feriadi H, Lim PY, Tham KW, Sekhar C, Cheong KW. Thermal comfort evaluation of naturally ventilated public housing in Singapore. Journal of Building and Environment 2002;37:1267–77.

[21] Han J, Zhang G, Zhang Q, Zhang J, Liu J, Tian L, et al. Field study on occupants' thermal comfort and residential thermal environment in a hot-humid climate of China. Journal of Building and Environment 2007;42:4043–50.
[22] Fanger PO, Toftum J. Extension of the PMV model to non-air-conditioned buildings in warm climates. Journal of Energy and Buildings 2002;34:533–6.
[23] Malaysian Standard, MS 1525: 2007 – Code of practice on energy efficiency and use of renewable energy for non-residential buildings. Malaysian Standard.
[24] Wong NH, Khoo SS. Thermal comfort in classrooms in the tropics. Journal of Energy and Buildings 2003;35:337–51.
[25] Yamtraipat N, Khedari J, Hirunlabh J. Thermal comfort standards for air conditioned buildings in hot and humid Thailand considering additional factors of acclimatization and education level. Journal of Solar Energy 2005;78: 504–17.
[26] Hwang RL, Yang KH, Chen PC, Wang ST. Subjective responses and comfort reception in transitional spaces for guests versus staff. Journal of Building and Environment 2008, doi:10.1016/j.buildenv.2007.12.004.
[27] Aynsley R. How air movement saves energy in indoor environments. In: AIRAH sustainability for tropical and sub-tropical climates conference. 2007.
[28] Orme M. Estimates of the energy impact of ventilation and associated financial expenditures. Journal of Energy and Buildings 2001;33:199–205.
[29] Fasiudin M, Budaiwi I, Abdou A. Zero-investment HVAC system operation strategies for energy conservation and thermal comfort in commercial buildings in hot-humid climate. International Journal of Energy Research 2010;34:1–19.
[30] Chaiyapinunt S, Phueakphongsuriya B, Mongkornsaksit K, Khomporn N. Performance rating of glass windows and glass windows with films in aspect of thermal comfort and heat transmission. Journal of Energy and Buildings 2005;37:725–38.
[31] Li HW, Lam NT, Wong SL, Tsang EKW. Lighting and cooling energy consumption in an open-plan office using solar film coating. Journal of Energy 2008;33:1288–97.
[32] Busch JF. A tale of two population: thermal comfort in air-conditioned and naturally ventilated offices in Thailand. Journal of Energy and Buildings 1992;18:235–49.
[33] Feriadi H, Wong NH. Thermal comfort for naturally ventilated houses in Indonesia. Journal of Energy and Buildings 2004;36:614–26.
[34] Li HW, Tsang EKW. An analysis of daylighting performance for office buildings in Hong Kong. Journal of Building and Environment 2008;43:1446–58.
[35] Evola G, Popov V. Computational analysis of wind driven natural ventilation in buildings. Journal of Energy and Buildings 2006;38:491–501.